Report as of FY2010 for 2009VT44B: "Quantifying Sediment Loading due to Stream Bank Erosion in Impaired and Attainment Watersheds in Chittenden County, VT Using Advanced GIS and Remote Sensing Technologies"

Publications

- Dissertations:
    - Garvey, K.M. Streambank Erosion in Chittenden County, VT: Application of Very High Resolution Remote Sensing and GIS Modeling. MSc Thesis expected in August 2011.
    - Pelletier, Keith C., 2011, Use Of Very High Resolution Remote Sensing To Estimate Sediment Loading Due To Stream Channel Migration, The Rubenstein School of Environment and Natural Resources, The University of Vermont, Burlington, Vermont. 139 Pages.
- Conference Proceedings:
    - Ishee, E. and D. Ross, Contribution of streambank erosion as a non-point source of phosphorus to Lake Champlain from streams in Chittenden County, VT. American Society of Limnology and Oceanography Conference, Feb 13-18, 2011, San Juan, Puerto Rico.

Report Follows

Final Report

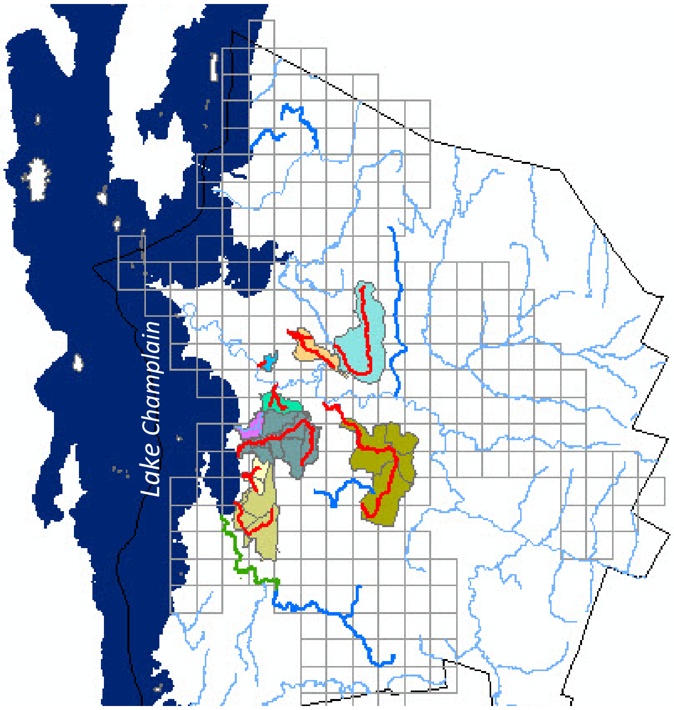
Title: Quantifying Sediment Loading due to Stream Bank Erosion in Impaired and Attainment Watersheds in Chittenden County, VT

Focus Categories: Nonpoint source pollution, sediments, fluvial processes
Research Category: Water Quality
Start Date: March 1, 2009
End Date: February 28, 2011
Principal Investigators: Leslie A. Morrissey (RSENR) and Donna M. Rizzo (CEMS)
Collaborators: Donald S. Ross (PSS) and Caroline Alves (NRCS)

Introduction: Streambank erosion is one of the most important yet least understood nonpoint sources of sediment and phosphorus threatening the impairment of surface waters within the Lake Champlain Basin. High spatial and temporal variability and the difficulties of measuring erosion rates at watershed scales limit our understanding and the ability to quantify the contribution of streambank erosion to water quality degradation. Previous research has not provided the quantitative basis to weight the importance of stream bank erosion relative to other sediment and P sources at watershed scales or the information needed to address within watershed variability in streambank erosion over time.

To address these issues, we combined remote sensing and field data to quantify sediment loading mobilized by streambank erosion in 15 Chittenden County watersheds. Three key subtasks were required to address our goal: 1) mapping of *erosion areas* due to channel migration over time using multidate imagery, 2) analysis of LiDAR-derived DEMs to quantify *streambank heights* that will be used to estimate soil volume loss, and 3) combined remote sensing and field observations to estimate sediment loading per eroded feature, reach, and stream. These analyses will allow us not only to efficiently quantify sediment loading mobilized by streambank erosion at watershed scales, but also to identify critical source areas that contribute a disproportionate amount of the total sediment load. Although most analyses were limited to single date LiDAR data, we also examined the value of multidate LiDAR data to partition sources of sediment (streambank erosion, channel erosion and deposition) and estimate total sediment loading within the Browns River watershed.

Study Area - Our research focused on 15 watersheds (Figure 1) in Chittenden County, VT, ten of which are on the state's 303d list of impaired waters [VT DEC, 2008] due to urban stormwater or agricultural runoff and six are identified attainment watersheds. The watersheds were selected because of long-standing federal, state and public focus on in-stream sediment, phosphorus, or fecal contamination and their contribution to water quality in Lake Champlain. These watersheds were also selected to leverage available aircraft and satellite imagery, LIDAR data, VT ANR RMP fluvial geomorphic assessments, USGS and UVM stream gage stations, and our previous channel migration mapping efforts in Allen Brook and Indian Brook watersheds. We also took advantage of LiDAR imagery from 2004 and 2007 along a portion of Brown's River.



Impaired watersheds
Allen Brook
Bartlett Brook
Centennial Brook
Englesby Brook
Indian Brook (south)
LaPlatte River (west)
Morehouse Brook
Munroe Brook
Potash Brook
Sunderland Brook

Attainment watersheds
Alder Brook
LaPlatte River (east)
Patrick Brook
Streeter Brook
Sucker Brook
Trout Brook

Figure 1. Chittenden County, VT study area showing 15 watersheds under study. Stormwater impaired streams are shown in red, the agriculturally-impaired LaPlatte River in green, and attainment streams in bold blue. The watershed areas associated with the stormwater impaired streams are also shown. The overlying grid indicates geographic coverage of CCMPO LiDAR data (acquired in 2004).

Methods: In support of efforts to map stream migration over time, USDA National Agriculture Imagery Program (NAIP) imagery and LiDAR data were acquired and compiled for the 15 identified streams in Chittenden County (Figure 1). Overhanging forest canopy cover unfortunately precluded mapping stream centerlines with the 2008 NAIP imagery (mid-summer coverage) for all but the LaPlatte River. Stream centerlines for the remaining streams were thus mapped using orthophotography collected during the spring leaf off period (CCMPO 1:1250 acquired in 2004) and compared to the 1999 (1:5000) VT Hydrography dataset. Channel migration was mapped as the lateral shift in stream centerlines between any two dates of observation (Figure 2) corrected for errors in image registration. The area of erosion associated with each shift in the stream centerline was then computed.

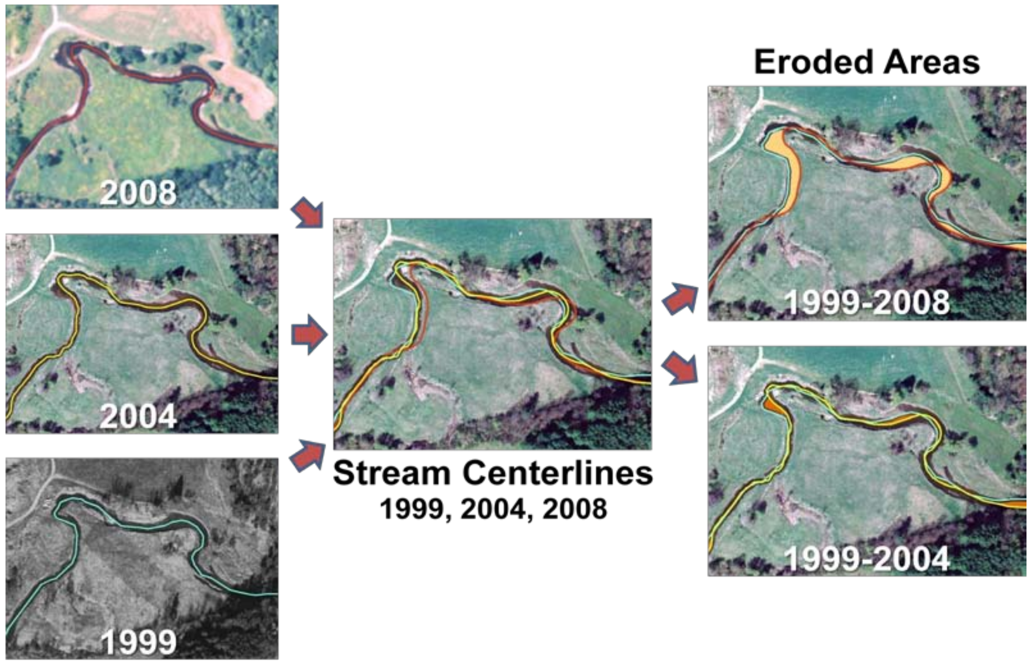


Figure 2. Stream centerlines were digitized for each image date and then overlaid to map stream migration over time (1999 – 2004; 1999 – 2008 for LaPlatte River).

Streambank and stream channel heights derived from the LiDAR data were used to calculate soil volume loss for each eroded area. In this effort, we employed 3.2m posting bare earth (BE) and reflective surfaces (RS) LiDAR data collected in May 2004. Enhanced DEMs were derived using Natural Neighbor spatial interpolation and by combining BE systematic point grids with low lying RS elevation points. The resulting BERS data (BE plus low-lying RS points layer) increased the resolution of the Allen Brook DEM by 168% and reduced the mean point spacing of the BE layer from 3.2m to 1.0m. Developed as part of this research effort, this enhanced product provided significantly greater horizontal and vertical resolution than conventional DEMs. We then calculated an upper soil volume loss estimate as the product of the eroded area derived from the multidate imagery and the streambank height derived from the LiDAR elevation data. Within the Browns River watershed multidate LiDAR were used to more accurately estimate soil volume loss and identify areas of channel erosion and deposition. All processing was automated using ArcGIS ModelBuilder.

Volumetric measures of sediment loading within each watershed over the period of study were estimated from the remote sensing and GIS analyses in combination with *in situ* soil and bulk density measurements completed in the summers of 2009 and 2010 in concert with D. Ross (Plant and Soil Science, UVM) and Carolyn Alves (USDA NRCS). Field teams sampled 76 randomly located erosion areas (with replicates) along Allen Brook, Indian Brook, Alder Brook, and the LaPlatte River.

Results: Large spatial and temporal variability in stream migration was observed over the 1999-2008 study period within each watershed as exemplified by the LaPlatte River (Figure 3). Over the stream length, the number of erosion features within each reach ranged from 0-65 (averaging 23 ±18). The number of eroded features was higher (578) for the 1999-2004 time period compared to the 2004-2008 time period (463).

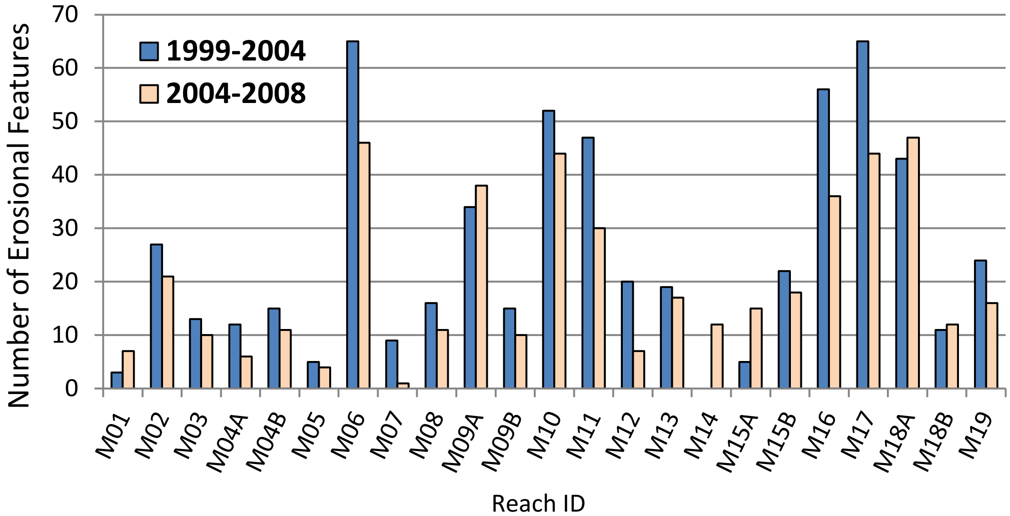


Figure 3. Number of eroded areas due to lateral stream migration summarized by reach for the LaPlatte River watershed (1999 – 2008).

Sediment load differed greatly by watershed ranging from 760 to 17,200 MT over the 5 year study period (1999 – 2004) and 0.12 to 4.6 MT m^{-1} when normalized by stream length (Figure 4). Reaches with large contributions of sediment were easily identified. As part of a collaborative project with D. Ross (PSS/UVM), these data also provided the basis for estimating phosphorus loading to Allen Brook. It was estimated that erosion due to lateral channel migration along Allen Brook (1999-2004) yielded 3 MT phosphorus or approximately 40% of the total P delivered to Lake Champlain from Allen Brook for that period. Our remote sensing-based estimates of soil loss due to streambank erosion represent a significant improvement over previous limited point sampling approaches and confirm that lateral channel migration represents a significant source of sediment and phosphorus loading in these streams.

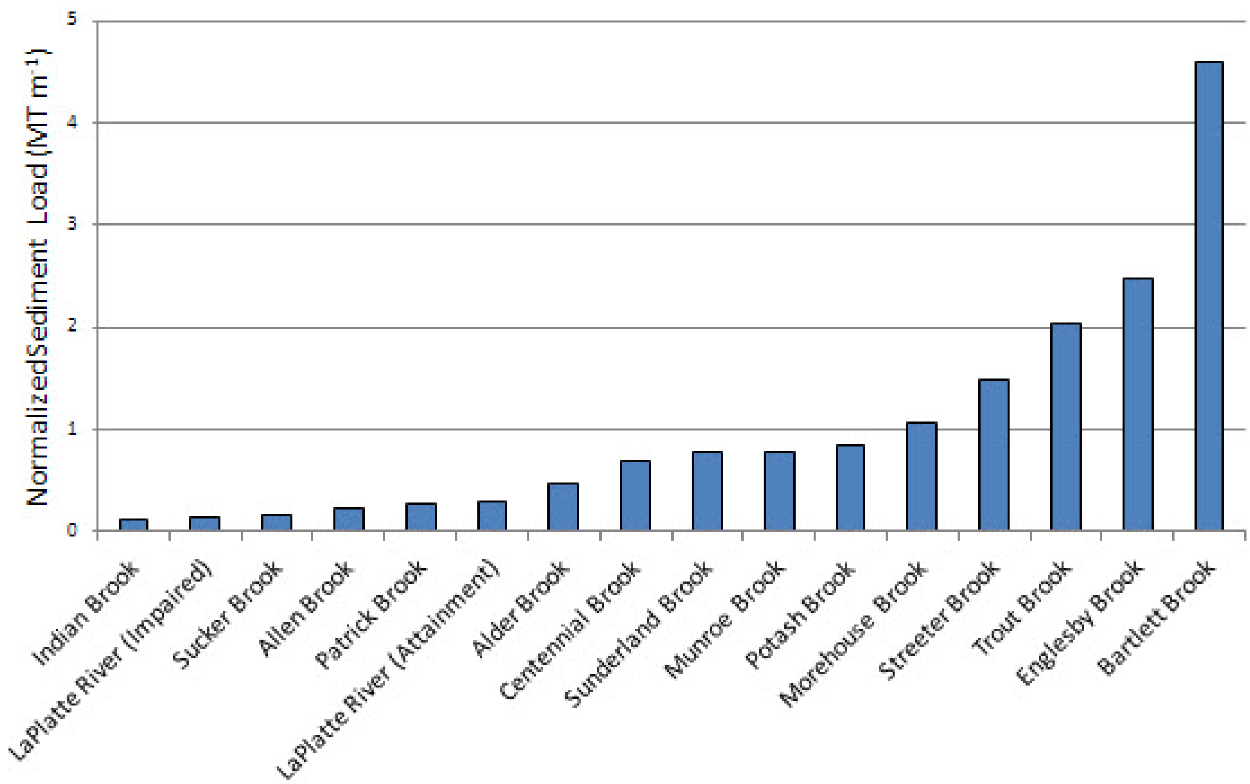


Figure 4. Sediment loading due to streambank erosion (1999-2004) normalized by stream length for 15 streams in Chittenden County, VT.

Within the Browns River watershed, DEMs were generated from LiDAR elevation data acquired in 2004 (3.2m posting) and 2007 (2.4m posting) that were then used to calculate channel erosion, deposition, and net sediment loading for 16 stream reaches. Results demonstrate that 9 reaches were dominated by erosion and 7 by deposition (Figure 5). Erosion and depositional processes within each reach were further analyzed based on VT ANR Phase 2 variables (e.g. grade and bedrock controls, bridges and culverts, stormwater inputs, and bank armoring and straightening) and geomorphic scores (aggradation, degradation, planform, and widening). Encroachment by development, stormwater inputs, straightening, and armoring of the banks lead to increased stream transport capacity and thus increased erosion while changes in the channel width, gradient, and confinement ratio support deposition. In addition to reach-level processes, erosion and deposition at locations within each reach have been identified. Our results also indicate that streambank erosion resulting from lateral channel migration represented from 0 to 26% of the total sediment loading contributed by channel processes on a reach-by-reach basis.

Reach ID	M07	M08	M09	M10	M11	M12	M13A	M13B	M14	M15A	M15B	M15C	M15D	M16A	M16B	M16C
Stream Type	E	F	E	E	E	C	C	B	C	C	E	C	E	B	D	C
Width:Depth (ft)	9.8	16.3	7.0	11.1	9.9	13.7	15.5		17.5	**26.5**	8.9	9.7	**41.3**	17.8	**37.9**	20.9
Slope (%)	0.4	0.8	0.8	0.7	0.2	0.3	1.9	1.9	0.8	0.2	0.2	0.2	0.2	0.7	0.7	0.7
Confinement Ratio	9.7	23.1	**95.3**	32.1	26.8	16.7	**2.0**	**2.0**	23.4	19.7	19.7	19.7	19.7	24.8	24.8	24.8
Bank Armoring (%)	7	16	8	4	17	13	8	8	17	1	1	1	1	**23**	**23**	**23**
Straightening (%)	**93**	**34**	**90**	12	**30**	9	0	0	**91**	**60**	**60**	**60**	**60**	25	25	25
Bridges / Culverts (%)	8	8	**20**	**20**	**30**	**10**	1	1	**10**	**7**	7	7	7	0.4	0.4	0.4

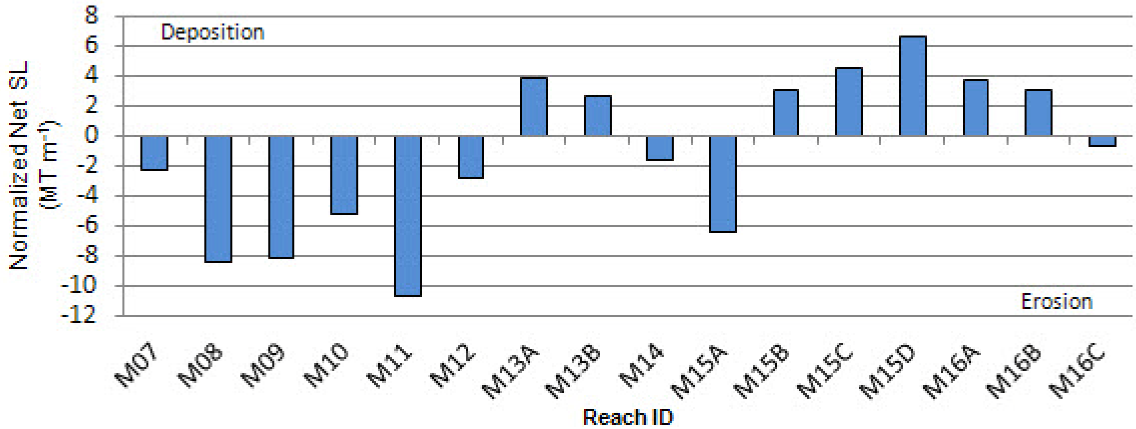


Figure 5. Net sediment loading (normalized by stream length) for Browns River reveals reach-level processes (erosion or deposition) that can be linked to VT ANR Phase 2 geomorphic variables (top pane). Extreme values are highlighted in the table.

Conclusions: The results of this study demonstrate the potential value of remote sensing to augment stream geomorphic and water quality management efforts by providing consistent, accurate and relatively low cost information on stream geomorphic change and sediment loading over time at reach and watershed scales. These analyses also serve as a baseline against which future estimates of sediment loading can be evaluated and as a means to constrain subsequent P loading estimates due to streambank erosion. Our methodology represents a departure from previous studies that measured or modeled channel migration and streambank erosion at specific sites by assessing stream migration along the entire stream length. More importantly, this effort represents not only a significant step toward systematically quantifying sediment (and P) loading due to streambank erosion throughout the Lake Champlain basin and elsewhere, but also a watershed-scale approach that can greatly aid adaptive management efforts. By automating this process within a GIS and leveraging high spatial resolution remotely sensed data acquired over time, we provide a rapid, reliable and cost-effective method to quantify streambank erosion rates and sediment loading in streams across northern temperate regions.

Student Support: Graduate student, Ms. Kerrie Garvey, joined the project team in July 2009 under the direction of Leslie Morrissey and Donna Rizzo (anticipated graduation August 2011, M.S., Natural Resources Program, RSENR/UVM). Two peer reviewed journal articles derived from Ms. Garvey's thesis are planned for submission in the fall of 2011.

Conference Presentations:

Garvey, K.M., L. A. Morrissey, D. M. Rizzo, and M. Kline, Streambank Erosion in Chittenden County, VT: Application of Very High Resolution Remote Sensing and GIS Modeling, *Lake Champlain 2010 Conference: Our Lake, Our Future,* Lake Champlain Research Consortium, June 7-8, 2010, Burlington, VT.

Garvey, K.M., L. A. Morrissey, D. M. Rizzo, and M. Kline, Quantifying Sediment Loading due to Streambank Erosion in Impaired and Attainment Watersheds in Chittenden County, VT, *Vermont Geological Society Winter Meeting*, Feb. 6, 2010, Norwich, VT.

Ishee, E. and D. Ross, Contribution of streambank erosion as a non-point source of phosphorus to Lake Champlain from streams in Chittenden County, VT. *American Society of Limnology and Oceanography Conference*, Feb 13-18, 2011, San Juan, Puerto Rico.